

# **Michipicoten River Hydroacoustic Study Using Split-Beam Sonar, 2004**

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MICHIPICOTEN RIVER HYDROACOUSTIC STUDY USING  
SPLIT-BEAM SONAR, 2004

by

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## ABSTRACT

Cronkite, G.M.W., Enzenhofer, H.J., Pellegrini, M., and Degan, D. 2005. Michipicoten River hydroacoustic study using split-beam sonar, 2004. Can. Tech. Rep. Fish. Aquat. Sci. 2576: iv + 45 p.

We collected split-beam hydroacoustic data with two different acoustic systems during the rainbow trout spawning migration in 2004 to determine if acoustic technology and methodology were an efficient and cost-effective approach to estimating the size of spawning populations of anadromous salmonids in the Michipicoten River. The acoustic site was approximately 1 km upstream of the mouth and met the physical requirements for effective acoustic data collection. Our testing demonstrated that fish actively migrate through this site, meeting another requirement for effective acoustic data collection. We estimated that the rainbow trout spawning population in 2004 consisted of about 1600 fish and we believe that the same methodology could be applied to enumerate Chinook and pink salmon during their fall spawning migrations in this river. Unlike Pacific salmon, which are semelparitic, rainbow trout are iteroparitic, which means that some individuals may be returning downstream to Lake Superior after spawning as other individuals are migrating upstream. Since estimates of the spawning population are based on a simple model that subtracts downstream targets from upstream targets, knowledge of target size corresponding to upstream migrating trout and spent trout moving downstream is needed to ensure that spawning population estimates are accurate. Target-strength measurements were made for various species present in the river for comparative purposes because some species (e.g., walleye) are approximately the same size as rainbow trout and could bias flux estimates if not accounted for during the estimation process. Species composition information needs to be collected through test fishing with drift nets or seine nets during future acoustic projects on this river. In-river accessory equipment to simplify fish enumeration and alternate acoustic technologies suitable to this river are also discussed.

## RÉSUMÉ

Cronkite, G.M.W., Enzenhofer, H.J., Pellegrini, M., and Degan, D. 2005. Michipicoten River hydroacoustic study using split-beam sonar, 2004. Can. Tech. Rep. Fish. Aquat. Sci. 2576: iv + 45 p.

Nous avons recueilli en 2004, à l'aide de deux sondeurs à faisceau scindé différents, des données hydroacoustiques pendant la montaison des truites arc-en-ciel afin de déterminer si la technologie acoustique et la méthodologie correspondante constituaient une approche efficace et rentable pour estimer l'effectif des populations reproductrices de salmonidés anadromes dans la rivière Michipicoten. La station se trouvait à environ 1 km en amont de l'embouchure, et répondait aux exigences physiques d'une collecte efficace de données acoustiques. Nos essais ont démontré que les poissons migrent activement par ce site, ce qui correspond à une autre exigence de la collecte des données acoustiques. Nous estimons que la population reproductrice de truite arc-en-ciel en 2004 consistait en 1 600 poissons environ, et nous pensons que la même méthodologie pourrait être appliquée au recensement des quinnats et des saumons roses pendant leur migration génésique automnale dans ce même cours d'eau. À la différence des saumons du Pacifique, qui sont semelpares, la truite arc-en-ciel est itéropare, ce qui signifie que certains individus peuvent redescendre vers le lac Supérieur après la fraye tandis que d'autres sont en remonte. Étant donné que les estimations de la population reproductrice sont basées sur un modèle simple qui soustrait les cibles d'aval des cibles d'amont, il est nécessaire de connaître les tailles cibles correspondant aux truites en montaison et aux truites vides en avalaison pour assurer l'exactitude des estimations. Des mesures de l'indice de réflexion ont été effectuées à des fins de comparaison sur plusieurs espèces présentes dans la rivière étant donné que certains poissons (p. ex. le doré jaune) sont à peu près de la même taille que la truite arc-en-ciel, ce qui pourrait biaiser l'estimation des flux migratoires si on n'en tient pas compte dans le processus. Les renseignements sur la composition spécifique seront recueillis grâce à des pêches expérimentales effectuées au filet dérivant ou à la senne au cours des prochaines campagnes acoustiques qui seront menées sur cette rivière. Nous examinons aussi la question de l'équipement accessoire mouillé qui peut simplifier le dénombrement des poissons, ainsi que d'autres technologies acoustiques qui conviendraient à ce cours d'eau.

## 1.0 INTRODUCTION

Both the Michipicoten River and Michipicoten Bay support significant sport fisheries based on resident (largely indigenous) and anadromous (mostly introduced) species (Table 1). The lower reaches of the river, below Scott Falls, provide excellent spawning habitat for these species. However, the abundance of many species is believed to be below historical levels at present (Pellegrini, pers. comm.). The factors affecting fish abundance in the Michipicoten River are not well understood but include over-fishing, exotic introductions and flow regulation for hydroelectric power generation. To manage these fish resources more effectively requires estimates of the fish populations in the river.

Previous attempts by the Ontario Ministry of Natural Resources to quantitatively assess the abundance of anadromous species spawning in the river were based on mark and recapture ratio estimates. Although various methods of fish capture were used, including trap nets, gill nets, seine nets and dip nets, all of these capture methods were inefficient and labour intensive. Fish capture weirs were also considered but because of the size of the river and the need to accommodate the passage of small watercraft, cost estimates were prohibitively high.

Under the auspices of the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (2002) (COA), the Wawa District office of the Ontario Ministry of Natural Resources received funding for a multiyear study of the best methods and new technologies for estimating migrating fish abundance. Following a feasibility study in which suitable methods and technologies are chosen, field testing of the chosen methods and technology would be undertaken. If a suitable technology could be found, future assessment efforts could be based on direct measures of fish population size.

During the design phase of the feasibility study it quickly became apparent that there was limited expertise with automated technologies for enumerating migrating fish in riverine environments in Ontario Canada. Based on literature searches and personal contacts, Fisheries and Oceans Canada, Science Branch at the Pacific Biological Station in Nanaimo, British Columbia Canada was contacted. This contact resulted in a collaborative agreement between DFO and OMNR and a service agreement with a recently retired DFO scientist to conduct a feasibility study of the potential for hydroacoustic enumeration on the Michipicoten River (Mulligan and Enzenhofer 2003). Several potential hydroacoustic sites were identified in the report and these choices were narrowed to a site and technology for testing.

Based on the findings of the feasibility study, the DFO and OMNR formed a partnership to accomplish phase two of the COA project in which site, acoustic technology and associated tracking software were tested. In addition a third party service provider, Pacific Eumetrics, was included in the project team to provide expertise with tracking software. This report documents the results of the second phase of the multiyear study and examines the operation and findings for the deployment of two split-beam

acoustic systems and tracking software during a portion of the rainbow trout spawning migration up the Michipicoten River in the spring of 2004.

Table 1. Major fish species found in the Michipicoten River, their origin, use of the river and relative abundance through time (Pellegrini, pers. comm.)

| Species                                           | Native Introduced | River Resident Anadromous | Spawning Period    | Perceived Abundance Through Time |         |
|---------------------------------------------------|-------------------|---------------------------|--------------------|----------------------------------|---------|
|                                                   |                   |                           |                    | Historical                       | Current |
| walleye<br><i>Stizostedion vitreum</i>            | N                 | RR, A                     | April/May          | High                             | Low     |
| northern pike<br><i>Esox lucius</i>               | N                 | RR                        | April/May          | Low                              | Low     |
| brook trout<br><i>Salvelinus fontinalis</i>       | N                 | RR                        | September /October | Medium                           | Low     |
| lake trout<br><i>Salvelinus namaycush</i>         | N                 | A                         | October/ November  | Unknown                          | Low     |
| lake sturgeon<br><i>Acipenser fluvescens</i>      | N                 | A                         | June/ July         | High                             | Low     |
| rainbow trout<br><i>Oncorhynchus mykiss</i>       | I                 | A                         | April/ May         | High 1960/70's                   | Low     |
| chinook salmon<br><i>Oncorhynchus tshawytscha</i> | I                 | A                         | August/ October    | High 1980's                      | Low     |
| coho salmon<br><i>Oncorhynchus kisutch</i>        | I                 | A                         | October/ November  | Low                              | Low     |
| pink salmon<br><i>Oncorhynchus gorbuscha</i>      | I                 | A                         | August/ September  | High 1970/80's                   | Medium  |
| lake whitefish<br><i>Coregonus clupeformis</i>    | N                 | RR                        | October/ November  | Unknown                          | Unknown |
| round whitefish<br><i>Prosopium cylindraceum</i>  | N                 | A                         | November           | Unknown                          | Unknown |
| longnose sucker<br><i>Catostomus catostomus</i>   | N                 | A                         | April/ May         | High                             | High    |
| white sucker<br><i>Catostomus commersoni</i>      | N                 | A, RR                     | April/ May         | High                             | High    |
| rainbow smelt<br><i>Osmerus mordax</i>            | I                 | A                         | May                | High                             | Low     |
| sea lamprey<br><i>Petromyzon marinus</i>          | I                 | A                         | May/ June          | High                             | Medium  |

Based on the feasibility by Mulligan and Enzenhofer (2003) we tested the split beam acoustic technology for enumerating migrating fish from April 27 to May 9, 2004.

Overall, the study had the following objectives:

1. To assess the ability of a split-beam hydroacoustic system in producing estimates of migrating salmonids using fixed location techniques. Work was done during the spawning migration period of rainbow trout (*Oncorhynchus mykiss*) and was felt to be valid for similar sized salmonids such as Chinook and pink salmon migrating during the fall months;
2. Determine additional electronic equipment requirements used in conjunction with the hydroacoustic system for covering the river cross-section where fish migration occurs;
3. To compare split-beam hydroacoustic systems produced by Hydroacoustic Technology Inc (HTI) of Seattle, Washington, and SIMRAD- KONGSBERG, a company in Norway;
4. To determine the types of in-river accessory equipment required to perform the monitoring effort as outlined in Enzenhofer and Cronkite (2000), Enzenhofer and Cronkite (1998); and
5. To make recommendations to OMNR based on the results of the acoustic survey for future monitoring of migrating fish in the Michipicoten River.

## 2.0 SITE DESCRIPTION

### 2.1 Study Area

The Michipicoten River is a large tributary to northeastern Lake Superior, approximately 8.3 kilometers SW of the town of Wawa Ontario Canada (Fig. 1). The site chosen for hydroacoustic testing was approximately 3.2 km downstream of the Highway 17 bridge where the river is approximately 70 m wide but can vary in width and depth based on the regulated discharge and spillage through the generating station. Access to the site was via an old road/power line right of way and by watercraft from the marina. The bottom substrate consists of fine sand and small gravel free of large boulders.

### 2.2 Site Selection

The test site was chosen using general criteria outlined by Enzenhofer and Cronkite (2000) which include:

1. A straight channel with laminar flow. Laminar flows produce less acoustic background noise than turbulent flow, resulting in an increased signal-to-noise ratio and hence, a greater ability to detect fish.
2. A planar bottom profile, rather than shelved or scalloped. A shelved bank creates riverbed zones that are inaccessible to the acoustic beam.
3. A bottom substrate free of large boulders that can interfere with the path of the acoustic beam or create turbulent flow.

4. Human activity on the river should be minimal because this may alter fish behaviour and affect the flux estimate (estimate of fish passage through the beam per unit time). Also, propeller wash from boats entrains air bubbles and creates background noise that can make fish detection more difficult.

5. Fish should be actively migrating and not holding or milling. Fish that tend to remain in the sampling area may be counted several times, which would lead to overestimates of flux.

### 3.0 MATERIALS AND METHODS

#### 3.1 Acoustic Data Collection

Two fixed location split-beam hydroacoustic systems produced by Hydroacoustics Technology Inc. (HTI) Seattle, Washington, and by SIMRAD-Kongsberg, Norway, were used during the study period. Measurements from a split-beam echo sounder provide three-dimensional target location in the beam as a function of time and allow target strength (TS – size of the return echo from an object) estimation (Traynor and Ehrenberg, 1990) and tracking of individual fish in four dimensions (time and 3D space). Data produced by the split-beam system and coupled with an automated tracking algorithm can provide reliable and timely estimates of fish passage (Ehrenberg and Torkelson 1996). Elliptical 4 X 10° beam transducers were chosen for use with both systems because this beam angle fit the slope of the streambed at our sample location (Enzenhofer et al 1998).

From the period of April 29 to May 3, we used a SIMRAD Model EK 60 split-beam hydroacoustic system operating at 120 kHz. The system consisted of a 4° x 10° elliptical transducer, a General Purpose Transceiver (GPT) and a processing computer. The GPT contains the transmitter and receiver electronics. The echo sounder was operated at 200W. The EK60 system sampled and stored digital sample data without threshold or compensation for signal loss. Pulse width during data collection was 0.256 ms with a pulse repetition rate of 8 pings per second. Off-line tracking and editing of files produced by the system were done using ECHOVIEW software Version 3.20. Although the Simrad EK60 system is capable of outputting detected single targets for fish tracking, we chose to use Echoview for this purpose. The data were amplified with a 40 LogR time-varied-gain and absorption coefficient of 0.0054 dB/m for target selection. Detected single targets were selected in Echoview meeting a -50 dB threshold, a pulse acceptance window between 0.08 and 0.77 ms for the returned echo, and within 20dB of the beam center (approximately 6° vertically and 20° horizontally).

We used an HTI Model 244 Digital Split-beam Hydroacoustic System (HTI 2000) operating at 200 kHz with a 4° x 10° elliptical transducer during the May 4-8 period. The echo sounder was operated at 24 dB re 1 W transmit power and -18 dB total receiver gain. The source level was 213.66 dB and the receive sensitivity was -168.41 dB. Acoustic signals were amplified with a 40 LogR time-varied-gain for target tracking.

Pulse width during data collection was 0.2 ms with a pulse repetition rate of 10 pings per second. Echoes were rejected if they did not meet the selected minimum amplitude of 200 mV, which is approximately equivalent to a -41 dB target on axis. We used a pulse acceptance window between 0.1 and 0.3 ms for the width of the returned echo. The processing computer contained HTI's software TS/INTEGRATION/TRACKER and both ABTrack and Polaris software routines for off-line tracking and editing of data files produced by the acoustic system (Pacific Eumetrics, 2002).

The main difference between the Simrad system and the HTI system and the rationale for testing both in the Michipicoten River, is that the Simrad system stores the raw signal down to -130 dB without a selected amplitude threshold, whereas the HTI system applies a selected threshold and filters the data for single-target selection and stores filtered data rather than the raw data. Although the Simrad is capable of storing detected single-target data similar to the HTI system, we chose not to store this data during sampling. Storing unfiltered data without a selected threshold allows a greater degree of flexibility in data processing, e.g. the processing threshold can be lowered when fish have lower target strength than expected; similarly, single-target detection parameters are best optimised by analysing collected data rather than setting a priori criteria based on expectations. Also, the digital sample data recorded by the Simrad system can aid in the interpretation of the filtered single-target data, especially when single-target detection is not optimised to the given conditions (e.g. fish species, behavior, background noise, boundary interference). Conversely, the filtered data produced by the HTI system is less voluminous and can be easier to process than the raw data recorded by the Simrad system. The choice of acoustic systems is often made according to site-specific fish behaviour as well as personal preferences and past experiences of the user.

### 3.2. Site Configuration

Each sonar system was operated from the right-bank (left- and right-banks are identified when facing downstream). Figure 2 presents a bathymetric view of the site and shows the location and arrangement of the equipment used. A small weir was erected to force fish to move offshore and pass through the acoustic beam in an area where it was larger, and therefore detection was optimal. The weir consisted of DuPont Vexar fencing which was attached to 2m long vertical T-bar stakes with diagonal bracing and placed every 2m perpendicular to the shoreline.

The acoustic transducer was attached to a dual axis rotator and placed on a tripod located on the upstream side of the weir (Enzenhofer and Cronkite, 2000). The Simrad system was deployed on a tripod 7 m from shore, in 1.2 m of water with the transducer 0.85 m above the bottom, and pitched down 3°. The HTI system was set 5 m from shore, in 1 m of water with the transducer 0.75 m above the bottom, and pitched down 2°. Underwater cables linked the transducer to the echosounder and the transducer-aiming unit to the rotator controller. Electronic components were housed in a mobile trailer and powered by a combination of a 12V battery and a 3 kW gasoline generator.

The transducer beam was aimed perpendicular to the shore and the maximum range set to 40 m, the point where the return signal from the surface or bottom would not exceed the minimum threshold set for accepting echoes. Figure 3 presents the three-dimensional co-ordinate system commonly used in riverine acoustics. The Y-axis is the up/down or surface/substrate direction, the X-axis is the upstream/downstream direction and the Z-axis is the range from the transducer perpendicular to the riverbank. For the right-bank of the Michipicoten River an upstream migrating fish would be traveling in the negative X-direction. Also shown in Figure 3 is the nominal beam width, labeled as the -3dB point, which is the point at which the acoustic power has dropped to half the power available at the beam axis. Given the beam pattern of the transducers, average-sized fish seen in the Michipicoten River should be detected within 2° and 5° of the acoustic axis.

### 3.3 Calibration

We tested the overall transmit and receive components for each acoustic system by collecting in-situ TS data on a calibrated sphere. A 38.1 mm tungsten carbide sphere which produces nominal TS of -39.5 dB in freshwater (MacIennan and Simmonds, 1992) was used for the 200 kHz HTI system and a 23.0 mm copper sphere with a theoretical value of -40.4 dB for the 120 kHz Simrad system. Results of our in-situ calibration produced -39.5 dB and -42.4 dB respectively. Because the Simrad calibration is nearly 2 dB less than expected, all TS data were adjusted by + 2dB to compensate. This error in the field calibration indicates that this borrowed Simrad system was in need of manufacturer calibration, but the TS measurements could still be used after the correction was applied.

### 3.4 Test Fishing and Tethered Fish Experiments

The Michipicoten River supports multiple species of fish (Table 1) which can confound the acoustic estimates for the targeted salmonid species. Species composition is a common problem in riverine work and sometimes the presence of non-target species can be detected and filtered based on track characteristics and/or acoustic size of the targets. Monofilament gill nets consisting of 2 m x 16 m panels with stretched mesh size of 2.54 cm to 11.5 cm were set immediately upstream of the transducer for 10-12 hours, in the area where fish passage occurred.

We collected acoustic data on live or fresh dead fish from the nets to determine if the TS could be used to differentiate common species in the river. Individual fish were harnessed with monofilament fishing line attached to their lower maxillary and were placed in the acoustic beam at approximately 10 m range. In addition, a live rainbow trout, angled near the acoustic site, was tethered in the same manner and allowed to freely swim in the acoustic beam.

## 4.0 RESULTS AND DISCUSSION

### 4.1 Site Characteristics and River Coverage

We began setting up the site and acoustic system on April 27 and data collection was initiated on the evening of April 28 with the Simrad system and the near-shore right-bank transducer. There was negligible fish activity at the site during the daytime period of the first day. It was not until the first 24 hours of data were viewed with an editor that we realised that most of the fish activity had occurred during the early morning period with what appeared to be directed upstream migration. For the first two days of data collection the fish passage during the early morning peak migration times was low, leading us to conclude that we started collecting data prior to the main migration of rainbow trout.

The acoustic site we chose was conducive to split-beam acoustic enumeration with the  $4^\circ \times 10^\circ$  beam closely fitting the bottom contour of the site. The bottom substrate was made up of stable mud and fine gravel and did not exhibit large obstructions such as wood debris or boulders. Figure 4 shows the cross-sectional area of the river that can be theoretically covered by a  $4^\circ \times 10^\circ$  elliptical beam, aimed at a  $-2^\circ$  angle relative to the water surface. We tested the actual coverage of the beam by collecting acoustic data on a 10 cm diameter, lead shot filled plastic sphere, because it has a TS similar to that of an adult Pacific salmon. The target was suspended from a 2.5 m long pole attached to the bow of an anchored boat. The target was passed through the vertical axis of the acoustic beam at approximately 5 m, 10 m and 20 m range. The target was visible in the beam from surface to substrate at each range, indicating that fish targets could be detected throughout the water column within the set range. Maximum range with this setup was about 40 m, beyond which bottom signals obscured smaller echoes from fish targets.

### 4.2 Tethered Fish Experiments

As expected, the test nets did not catch large numbers of fish, due to the short net lengths and short overnight sets that were used during the period of May 3-5 (Table 2). We note that rainbow trout were not captured in the gillnets, which may mean that the net did not effectively cover the area of rainbow trout migration or that the rainbow trout were able to avoid the net. The one rainbow trout we used for our TS measurements was caught by angling in the vicinity of the acoustic site. Test fishing to determine species composition is one area where more work is required because an independent measure of species composition is needed for the acoustic data.

Table 2. Gill net effort and catch results.

| Date  | Duration hrs. | Net Length | Catch                                  |
|-------|---------------|------------|----------------------------------------|
| May 3 | 10.5          | 30 m       | 1 longnose sucker<br>1 white sucker    |
| May 4 | 12.25         | 91 m       | 4 longnose sucker<br>1 round whitefish |
| May 5 | 11.5          | 61 m       | 10 longnose sucker<br>1 lake whitefish |
| May 5 | 12.0          | 30 m       | 1 walleye<br>1 longnose sucker         |

The results of the TS measurements are presented in Figures 5 and 6. The species tested were a longnose sucker 56 cm fork length, a round whitefish 41 cm fork length, a walleye 51 cm fork length in a bloated and non-bloated state, and a rainbow trout 65 cm fork length. The walleye included in the analyses had begun decomposing, producing gas, which distended the digestive tract. Since much of the sound reflection is from the swim bladder gasses in the species where a swim bladder is present, this made us curious about the effect of excess gas in the bloated fish on the TS measurements. After measuring the bloated walleye we punctured the digestive tract, releasing the gasses but leaving the swim bladder intact, and then re-measured the TS.

The TS of the punctured walleye was most similar to the TS of rainbow trout (Figs. 5 and 6). The dB scale is logarithmic and so a 3 dB increase in the measured TS corresponds to doubling of target size with respect to the strength of the returning signal. Based on our TS data, we believe that a TS filter can be used to differentiate rainbow trout from other species, except possibly walleye, for the purposes of obtaining an estimate of the rainbow trout population during this study. If the numbers of walleye are small in comparison to the numbers of rainbow trout (or pink or Chinook salmon) travelling up the river to spawn, then this would not pose a problem to obtaining a count by species. Longnose suckers were the most common fish observed in the river and the one we measured was particularly large, but displayed a mean TS more than 3 dB smaller than that measured for rainbow trout. We hypothesise that suckers may not maintain high volumes of gas in their air bladders because of their bottom-oriented behaviour and may therefore present smaller TS values than a fish of similar size that is less benthic in its behaviour. We hypothesise that the rainbow trout caught by angling may have showed a lower TS than it would have if left undisturbed, as the struggle during capture tends to cause expulsion of gasses from the swim bladder due to muscle contraction. In general the TS values of the larger fish, which we believe to be rainbow trout, showed higher TS than our test fish, averaging -29.4 dB (Fig. 7).

### 4.3 Fish Detection

Figure 8 presents typical echograms for the Simrad and HTI systems to give examples of how the data appears to the acoustician. Fish detection was good with both acoustic systems in this river. The background noise was well below the level of the fish targets of interest allowing good detection. Changes in water levels were gradual during the time of this study and we never had problems with high water events causing excessive noise or interference with equipment deployment as a result of the faster, more turbulent flow.

### 4.4 Fish Traits and Behaviour

Figure 9 presents the TS distributions for all of the fish we measured with the two acoustic systems. This includes fish travelling in the upstream and downstream direction. The TS mean and distribution for the later season HTI data showed a decrease in mean TS for this part of the season. This decrease in TS is consistent with either an increase in the number of smaller fish later in the season which may be species other than rainbow trout, or with a decrease in the target strength of rainbow trout that had spawned and were returning downstream to the lake. Figures 10 and 11 display a general increasing trend in the numbers of large and small downstream travelling fish later in the season. The latter interpretation is compatible with our knowledge of fish physiology in that lower TS values after spawning are likely due to the decrease in fat content of the body due to the release of gametes and depletion of fats in the flesh (Reid et al, 1993). Alternatively, the increase in acoustically small targets is consistent with an outmigration of smaller predator species that feed on rainbow eggs during spawning and begin to leave the system to look for alternate food sources after the rainbows have completed their spawning activities.

The possibility that the TS of rainbow trout may be lower after spawning has ramifications for obtaining a count of the spawning population. In a perfect scenario, if the acoustic system was deployed for a long enough period of time, then we would count the entire rainbow population travelling upstream to spawn and the surviving fish as they travelled downstream into the lake. Most riverine situations where acoustics are used to enumerate Pacific salmon only need to account for salmon as they move upstream past the enumeration site. The carcasses or moribund fish may drift downstream past the acoustic site, but Pacific salmon usually do not migrate back down the river and so are not factors in the count. This difference in biology needs to be taken into account in obtaining an accurate count of rainbow trout. Simply subtracting the downstream count from the upstream count is not valid for the rainbows, especially later in the season, because it would negatively bias the population estimate since some of these downstream fish above the TS filter value may have already spawned. Fish that fall below the TS cutoff after spawning will not bias the count if they are excluded.

Figure 7 presents the TS distributions of those fish we believe are large enough to be rainbow trout. The data from the two acoustic systems are similar in their distributions

and means. We have used a cutoff point of -33 dB and greater for rainbow trout based on previous experience with similar size sockeye salmon and our preliminary inspection of the data collected at the Michipicoten River. A 65 cm fork length rainbow trout displayed a mean TS of approximately -33 dB, which we believe may be somewhat lower than from a wild fish measured in situ due to handling effects. Sockeye salmon of similar size from the Fraser River, British Columbia, would exhibit TS values of -33 dB and greater (Enzenhofer and Cronkite, 2000). Furthermore, if the cutoff value is changed, the upstream:downstream ratio for small fish begins to deviate from the 1:1 ratio specified by the model used to estimate upstream flux, which assumes resident fish are equally likely to move upstream or downstream past the acoustic site. Thus, we believe that for a first attempt, and to allow an estimate of the rainbow population to be made for 2004, the Michipicoten River acoustic data support the use of a -33 dB cutoff. Fish smaller than -33 dB are milling resident species that are not directed in their movements toward the spawning grounds. More work is required on the TS filter in the future and as data on TS distributions are added each season, a clearer picture of the range of rainbow trout TS values will emerge.

Figure 12 presents the TS distribution for the smaller fish that we feel are probably not rainbow trout. Fish in this category were generally very small with the mean TS for both systems in the -36 to -37 dB range with some as small as -46 dB. The -36 to -37 dB mean TS corresponds with the value we measured for the longnose sucker (Fig. 5a). Longnose suckers were the most abundant species observed and caught in the test nets.

Figures 13 and 14 present the measured TS distributions and means for upstream and downstream fish from the Simrad and HTI systems, respectively. The TS distributions are similar and the means almost identical for upstream and downstream targets measured by the Simrad system (Fig. 13), which we interpret as an indication that we are measuring the same population of fish travelling in both directions. In contrast, the TS data from the HTI system, while similar to the Simrad system for upstream targets, show a marked decrease in the mean TS of downstream moving targets. Since the HTI data were collected later in the migration, we suggest that some of these downstream TS data are measurements from spawned-out fish returning to the lake, as mentioned earlier in this report.

Figure 15 is a side-view plot showing the distribution of all targets detected on May 03, which was the highest passage day when using the Simrad system. The plot shows the distribution of both upstream and downstream targets and we can see that the distribution is similar for targets travelling in both directions. The fish are bottom oriented and the majority are travelling at a range of 10 to 25 m from the shore. The transducer was aimed at a steep angle and was hitting the bottom at close range. We did not realize the relationship between aiming angle and the substrate until near the end of the time working with the Simrad system when we had a chance to plot the geometry. We were able to aim in this manner without interference from the substrate because the silt and sand substrate at this site is far more sound absorbent than rock or gravel, which would produce a very strong return signal that would interfere with the fish signals. As

mentioned previously, fish can be detected beyond the -3 dB area. With this Simrad transducer we could detect a -32 dB target at the surface of the water, which was well beyond the -3 dB area of the acoustic beam. We adjusted the aim approximately 2° up when we used the HTI system so that the top of the beam was parallel to the surface.

Figure 16 presents the distribution of the same targets as in Figure 15 but the targets are marked according to their acoustic size category. The plot shows that there is no difference in the distribution of the small and large targets. Therefore all of the fish passing the site are swimming in the same area of the river. We also note that target density decreases toward the deeper section of the river on the left-bank in both Figures 15 and 16. Although based on our experience we believe that there is minimal rainbow trout migration near the left bank due to the higher current velocities in this area, some effort should be made to address this issue and ensure that fish are not migrating upstream undetected on the far bank. Two approaches that could be used on the left-bank include (1) the setup of a weir to force fish offshore into the right-bank acoustic beam, and (2) setting-up an acoustic system on the left-bank to see if fish use the left-bank for migration. Note that in Figures 15 and 16 some fish targets appear below the substrate because of small errors in measuring the bottom contour combined with the fact that split-beam systems have larger error when measuring the up/down and left/right positions than they do for measuring range.

The distribution of fish targets detected with the HTI system across the river cross-section (Fig. 17) is similar to that measured with the Simrad system although a higher number of targets appear to be located closer to the surface. As with the Simrad system a -32 dB target could be detected from surface to substrate at ranges beyond 3 m from the transducer. Figure 18 shows only the large TS fish which we believe to be the rainbow trout detected by the HTI system. We note that the fish travelling upstream are strongly bottom oriented; possibly using ground effects to reduce swimming energy output against the current flow (Hinch and Rand, 2000). Fish travelling downstream tend to be more randomly distributed throughout the water column. This difference in the mean location of upstream and downstream moving targets was not seen as strongly in the Simrad data and may be another indication of spawned rainbow trout travelling downstream to the lake. The distribution of small targets in Figure 19, which correspond to small fish, is similar to that of rainbow trout; small fish tend to be somewhat bottom oriented when travelling upstream but are randomly distributed throughout the water column when travelling downstream.

Figure 20 presents the overall run timing curves for the Simrad and HTI data combined. The plot includes all targets detected. On May 01 the Simrad system did not collect data for the early morning high passage period due to a laptop computer malfunction. We did not extrapolate from the data collected on April 30 and May 02. Datasets from all of the other days are complete. The upstream data displays three distinct peaks in activity while the downstream count increases as the season progresses.

Figure 21 presents the run timing curves for large targets greater than or equal to -33dB. The pattern is very similar to the overall run timing curve in Figure 20 except that

the downstream count does not increase gradually as the season progresses. The proportion of downstream counts to upstream counts appears to stay the same as the upstream counts vary. In contrast, although the run-timing pattern of small upstream targets is similar to that for large fish, the proportion of downstream fish increases dramatically towards the end of the season (Fig 22). This pattern is consistent with upstream rainbow spawning migrations followed by downstream returns.

Figures 10 and 11 present the cumulative run sizes for both large targets and small targets. For the large targets, which we hypothesise are rainbow trout, the total upstream population is approximately 1600 fish (Figure 10). 1600 fish should be considered an underestimate because one overnight period of Simrad data was missing and because there is uncertainty concerning the identity of some of the large downstream fish; some of these targets that we subtracted may have been spawned-out rainbow trout returning to the lake. Figure 11 shows that the ratio of small upstream and downstream migrants is approximately 1:1 on most days, which supports the use of our TS cut-off for separating the resident species from the migrating rainbow trout. We would expect that resident species would move randomly upstream and downstream, as they are not driven to reach the spawning grounds at this time of year.

The average hourly counts of large and small targets are shown in Figures 23a and b, respectively. There is a strong pattern of peak migration from 1:00 am to 8:00 am, regardless of target size, making this a critical time for data collection. If this period is not sampled, as occurred on 01 May during our study, it is much more difficult to extrapolate a count than it is on a river where fish are migrating more uniformly throughout the day. We also note that the proportion of downstream targets is higher for small fish and that small fish downstream activity tends to occur throughout the day. These observations seem to be consistent with the designation of small targets as resident species.

Figure 24 presents the speed distribution histograms for the data taken with the HTI system. We present the speeds from the HTI data as we have developed software routines that calculate the X-speed (speed in the upstream/downstream direction) of tracked targets. This measure of fish speed was accurate when tested experimentally (Cronkite and Enzenhofer, 2002, Cronkite et al, 2004). The distributions of fish speed through the beam were remarkably similar for large fish and small fish in both the upstream and downstream directions. Both large and small fish travelled more slowly in the upstream direction and considerably faster in the downstream direction. The small fish displayed a faster average speed in both the upstream and downstream directions.

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study for the period of April 29 to May 9, 2004 we are confident that we can produce flux estimates of fish passage for the Michipicoten River that are precise and correct according to the protocol that we use. The site we tested is ideal for acoustic enumeration by split-beam or other acoustic methods based on substrate, bottom contour and flow conditions and unusual fish behaviour (e.g. holding,

milling) was not observed, rather fish actively migrated upstream past the site. Weirs extending out from the left- and right-banks will be required to achieve the count, but these structures are easily built and deployed, and are not large scale. If the salmon species spawning in the river display the same migration behaviour as the rainbow trout, then counts of the salmon species can also be made.

The principal uncertainty in the Michipicoten River is apportioning species composition in the acoustic data. This is a problem on many river systems and is often addressed with test fisheries of various kinds. We feel that a limited, nighttime drift-net test fishery is appropriate for the Michipicoten River. Drift netting at night is more difficult to undertake, but the addition of shore/boat lighting would allow it to take place. We do not believe that the netting needs to be extensive, but sufficient to back up the assumption that the larger migrating fish are predominantly rainbow trout.

### **5.1 System Configuration**

Either the Simrad or HTI digital split-beam hydroacoustic system coupled to a  $4^\circ \times 10^\circ$  elliptical beam transducer can be used to monitor fish passage in the Michipicoten River. Both systems will produce sufficient quality data that can utilise single echo detection tracking algorithms. Collecting unthresholded and unfiltered Simrad data can be of benefit when the acoustic expertise of the staff is limited, as mistakes in setting the data collection parameters or changes in the river conditions would likely not lead to lost data. Also, digital sample data and the ability to vary single target parameters after data collection provide clues when questions arise in the interpretation of the data. However, the degree of acoustic expertise required to analyse the Simrad data is somewhat higher than for the HTI data.

For operations at this site, a  $4^\circ \times 10^\circ$  transducer should be placed on the right-bank, approximately 5 m from shore, less than 0.5 m off the bottom, and aimed at an angle of  $-2^\circ$  with the acoustic beam perpendicular to the current flow. This configuration allows 45 m of the river cross-section to be monitored, leaving approximately 15 m of the left-bank uncovered, and should cover the area shown in the fish density plots (Figs. 15 to 19) where the majority of passage occurred. A temporary weir, trapezoidal in shape, and 10 m in length, would be placed on the left-bank. The right-bank would have a sectional weir (Fig. 25), approximately 18 m long, to divert any near shore fish passage offshore and through the area where the acoustic beam is larger.

### **5.2 In-river Accessory Equipment**

The following is a list of In-river accessory equipment recommended for use in conjunction with the hydroacoustic system.

- Adjustable Pole Mount
- Modified step-ladder
- Left-bank fish deflection weir
- Right-bank fish deflection weir
- Boom and winch system for installing/removing weir sections

### Adjustable Pole Mount and Modified Step-ladder

Multiple transducer aims are not needed to cover the river cross-section at this site. Substantial cost savings can be achieved by deploying the transducer from an adjustable pole mount (Fig. 26), originally designed to for the DIDSON acoustic imaging system by the Applied Technologies group of DFO (Enzenhofer and Cronkite, 2005). The mount attaches to boat gunnels or to a modified stepladder (Fig. 27) anchored to the river bottom with four 5/8 inch steel pins. The adjustable pole mount allows the user to adjust the transducer height in the water column and aim a transducer to the desired position up/down and/or left/right. Pitch angle of the transducer beam can be read directly off a graduated crank arm and pointer that clamps to the main pole. Use of the adjustable pole mount and stepladder would replace the dual-axis rotator, rotator controller, associated software and tripod used in our study.

### Left-bank Weir

A short weir should be installed on the left-bank to force fish that travelling in the near shore area of this deeper and faster current flow toward the ensounded area on the right-bank. The left-bank has a steep gradient and consists of loose gravel, which tends to slide into the river. We anticipate driving a 2.54 cm rebar anchor pin near the water edge and attaching a 10 m long trapezoidal shaped weir. The deep end of the weir can be held in place by using guy lines attached to shore anchor pins with rope pullers placed upstream and downstream of the weir. Cleaning debris from the weir would be accomplished by releasing the upstream rope puller and allowing the weir to pivot downstream on the anchor pin. River current flow would then self clean the weir. To re-deploy, a rope puller could be used to winch the weir back into the upright position.

### Right-bank Weir

A stationary weir, similar to the design used on the Fraser River (Enzenhofer and Cronkite 2000) would be constructed for the right-bank (Fig. 25). Weir design must accommodate changes in water levels resulting from flow regulation for hydroelectric generation. During our study period the water level fluctuation was 0.54 m and changed gradually. The weir would be approximately 18 m in length (5 sections) and would have a walkway and handrail for its entire length. This style of weir will provide access to the transducer and can be easily cleaned by removing individual vertical pipes. This weir is intended to be a temporary structure that would be removed at the end of the season. Coast Guard approvals under the Navigable Waters Protection Act are required for such in-river structures even if they are used only seasonally.

### Boom and Winch System for Installing/Removing Weir Sections

Shown in Figure 28 is a 4.1 m long boom and mounted trailer winch which allows installation of additional weir sections from the end of the last installed section. We

recommend this structure for the right-bank of the Michipicoten acoustic site to allow construction of the weir from shore, ease of access to the transducer and adjustability of the weir length and transducer position for varying water levels.

### **5.3 Test Fishing**

Apportioning the acoustic estimate by species when multiple species are present will require some method of obtaining independent species composition data. Results from this work indicate that peak migration hours for the majority of rainbow trout were during the hours of darkness. We suspect that other Pacific salmon species present in the Michipicoten River, such as Chinook salmon and pink salmon, may migrate throughout the day. Visual identification is difficult at any time and therefore some method of periodic net sampling in conjunction with the acoustic estimate should be implemented.

There are two basic methods for capturing fish with nets. One method is to set monofilament gill-nets of various mesh sizes in the area where fish passage occurs. This method was used by OMNR to capture fish for the acoustic TS evaluation of different species for this report (Table 2). The second method is to drift a net through the area of interest. The net would be played out from a moving boat, drifted through the study area and then recovered at the end of the drift. Drift nets are effective in sampling a large area of the river in short time duration.

We recommend the drift net method for the Michipicoten River as the river bottom was clear of snags and has a favourable flow rate at the acoustic site. Drift net and seine net sampling can be done in the hours of darkness with the addition of some shore lights. There are two choices of net:

1. A beach seine consisting of 5 cm mesh nylon twine suspended by a cork line and heavy lead line. Net lengths generally range from 20 m to 60 m with the number of mesh hung to allow a slight belly in the net while being drifted. Beach seines are commonly used in mark-recapture programs carried out in major salmon spawning streams in British Columbia as they allow fish to be held and released unharmed. The downside of the beach seine is that at least four people are required to safely perform the drift due to their heavy drag once fully deployed. An ATV could also be used to assist in pulling in the net at this site.
2. A drifted monofilament gillnet commonly used in the commercial fishing industry. These nets can be ordered in varying mesh sizes, depth of net and length according to the user specification. Net deployment is from the boat similar to the beach seines but requires only two people to perform as they have less drag when fully deployed. The nets would require immediate picking to release fish unharmed and may at times cause damage to some fish.

### **5.4 DIDSON Imaging Sonar**

The Stock Assessment division of DFO recently purchased a DIDSON acoustic imaging system for spawning ground assessment work (Sound Metrics Corporation,

2004). During the period of July 13 to October 22, 2004 the Applied Technologies group tested the high-resolution sonar on several major sockeye salmon (*Onchorhynchus nerka*) producing rivers of the Fraser River watershed. Assessment work consisted of comparative counts of files collected with the DIDSON unit to either visual tower counts or to a weir count. Preliminary results indicate that the DIDSON sonar system is effective in detecting fish passage on its high frequency setting to 12 m range. We tested the low frequency setting, user selectable to 42 m range, on holding Chinook salmon out to 22 m range. We feel that the use of the DIDSON system is a viable option for the Michipicoten River and would be worth testing in the 2005 rainbow trout season. The DIDSON system may also have potential for determining species composition due to its high resolution, but this aspect of data analyses is developmental at this time.

### ACKNOWLEDGEMENTS

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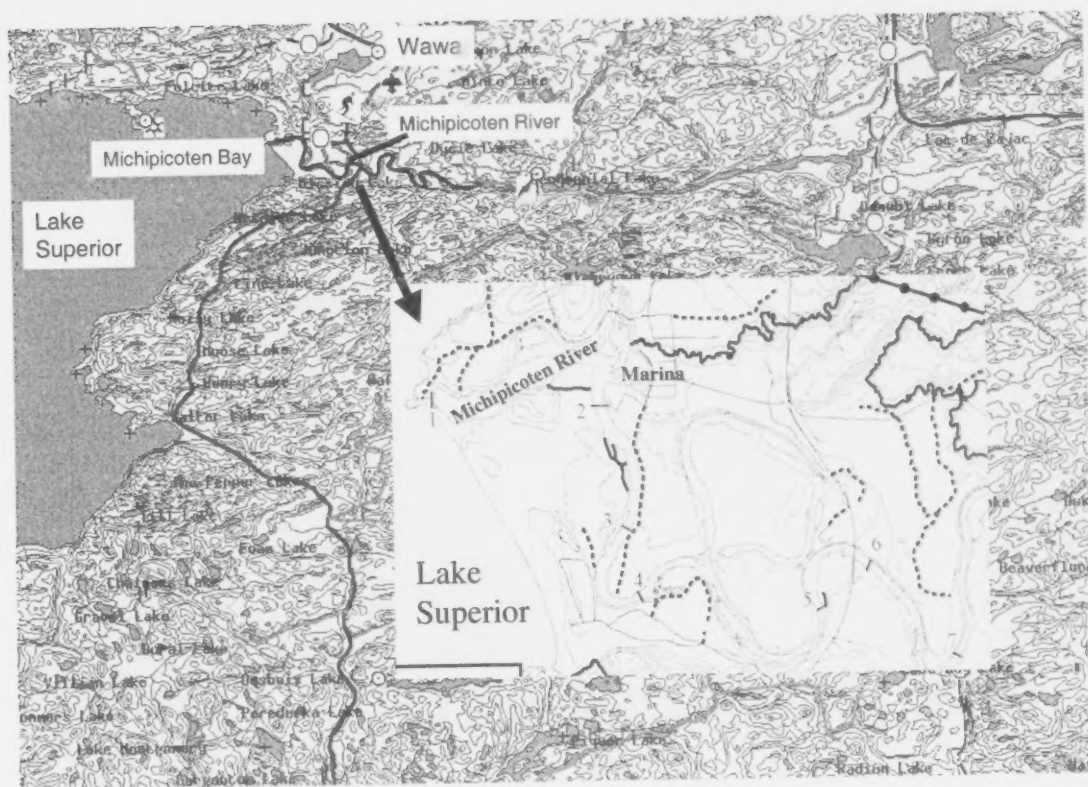


Figure 1. Area map of the Michipicoten River study area. The sites marked 1 to 7 on the inset map were potential acoustic sites identified by Mulligan and Enzenhofer (2003). Site 4 was the most suitable site and was used for this study.

## Michipicoten River Sonar Site, May 2004

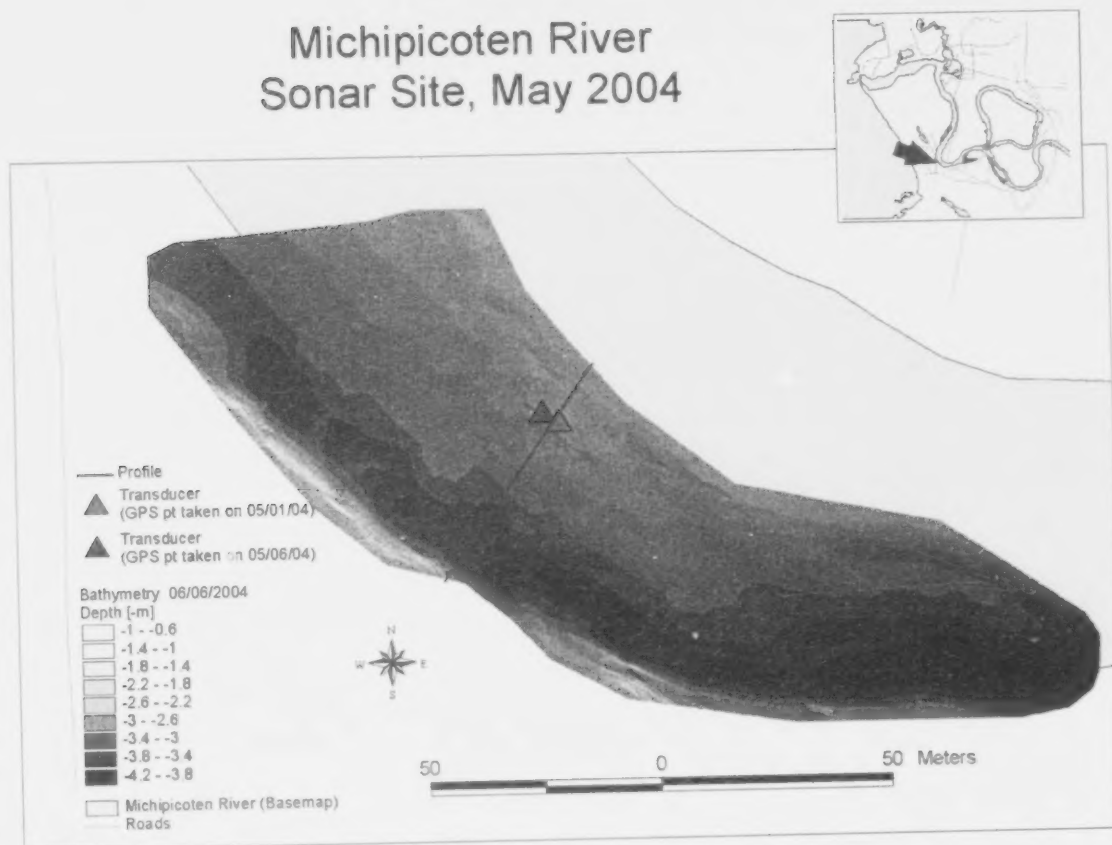


Figure 2. Bathymetric plot of the chosen acoustic site on the Michipicoten River. The bathymetric plot does not directly overlie the channel derived from the 1:50,000 basemap, possibly due to a change in the river channel since the maps were made or GPS error at the time of the survey.

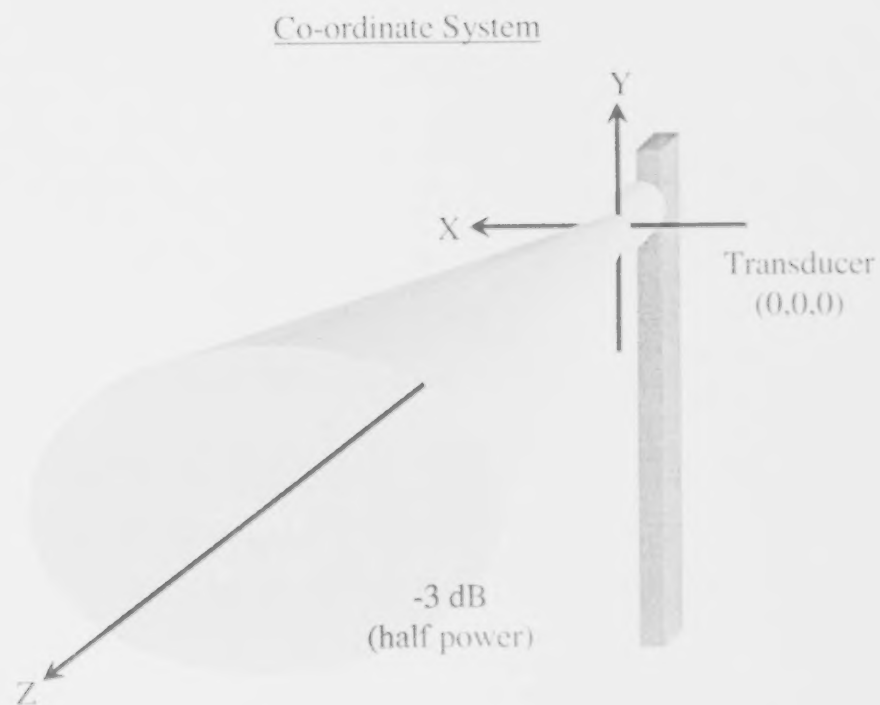


Figure 3. Co-ordinate system commonly used for riverine acoustic work. The elliptical cone represents the sound beam emanating from the cylindrical transducer.

Co-ordinate System

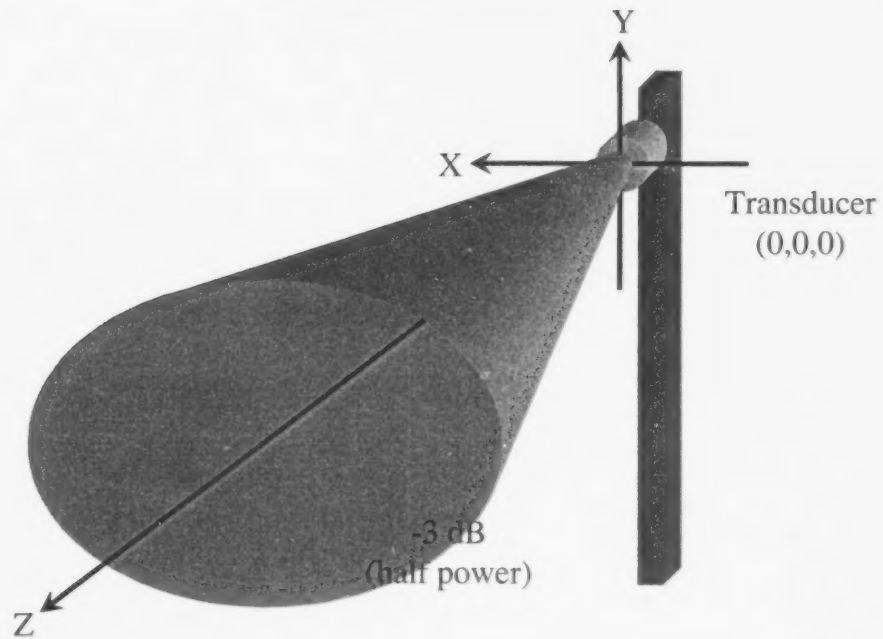


Figure 3. Co-ordinate system commonly used for riverine acoustic work. The elliptical cone represents the sound beam emanating from the cylindrical transducer.

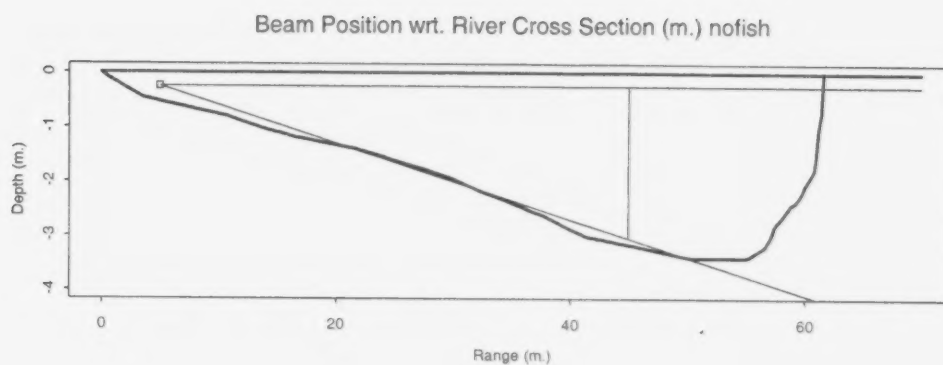


Figure 4. Bottom profile in side view of the Michipicoten River acoustic site. The horizontal line at depth 0 is the water surface and the thick black curve outlines the river depth at range from the shore. The thin radiating black lines mark the vertical boundaries of the  $4^\circ \times 10^\circ$  beam at the -3 dB point (half-power). The thin vertical line marks the maximum range used to collect data.

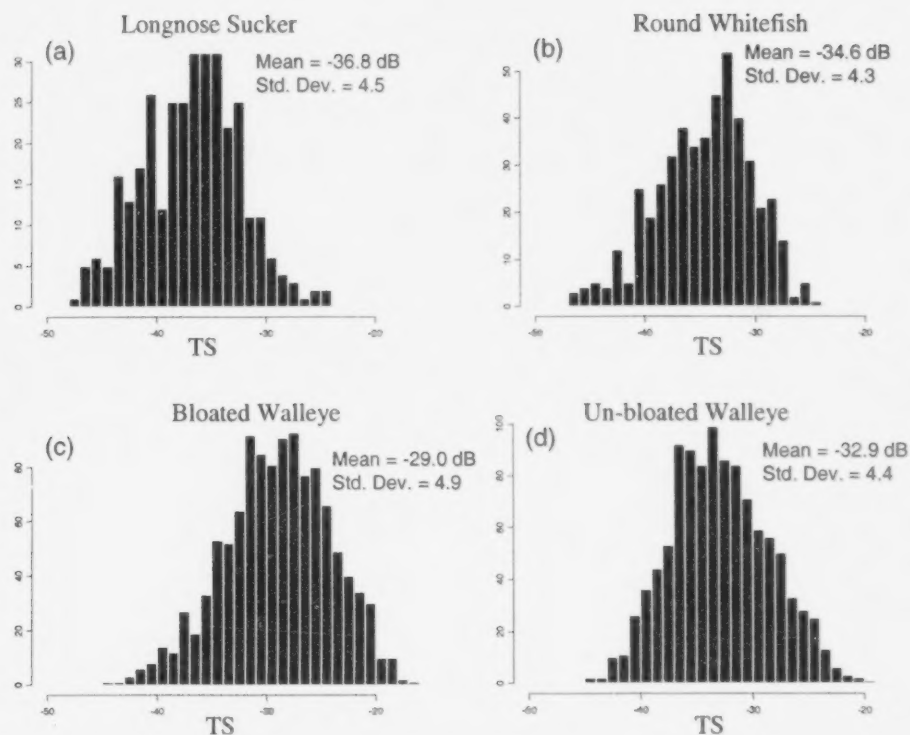


Figure 5. Histograms of measured ping-by-ping TS values of the fish species measured with the HTI system. (a) Longnose Sucker, (b) Round Whitefish, (c) Bloated Walleye, and (d) Unbloated Walleye. The wide range of TS values are due to the movement of the fish targets which presents different fish aspect angles to the transducer. The mean TS and standard deviations are also presented.

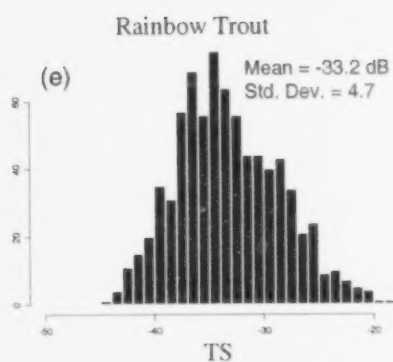


Figure 6. Histogram of measured ping-by-ping TS values of the rainbow trout measured in the same manner as those species presented in Figure 5.

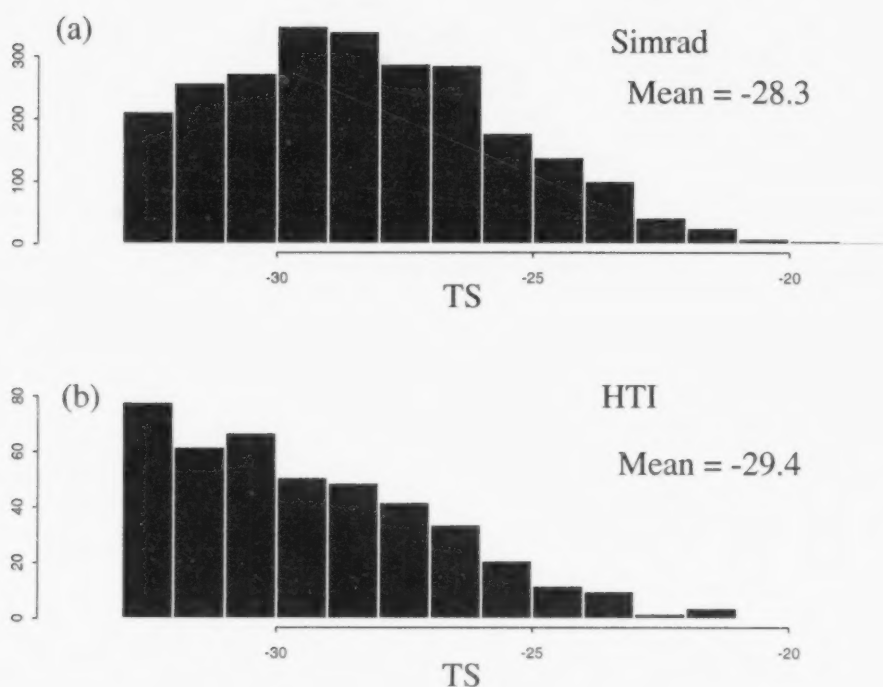


Figure 7. Target strength distributions of fish tracks greater than or equal to -33dB which are believed to be rainbow trout travelling both upstream and downstream, measured with (a) the Simrad system and (b) the HTI system. Mean TS values are presented. Note that the data was collected with the two systems at different times.

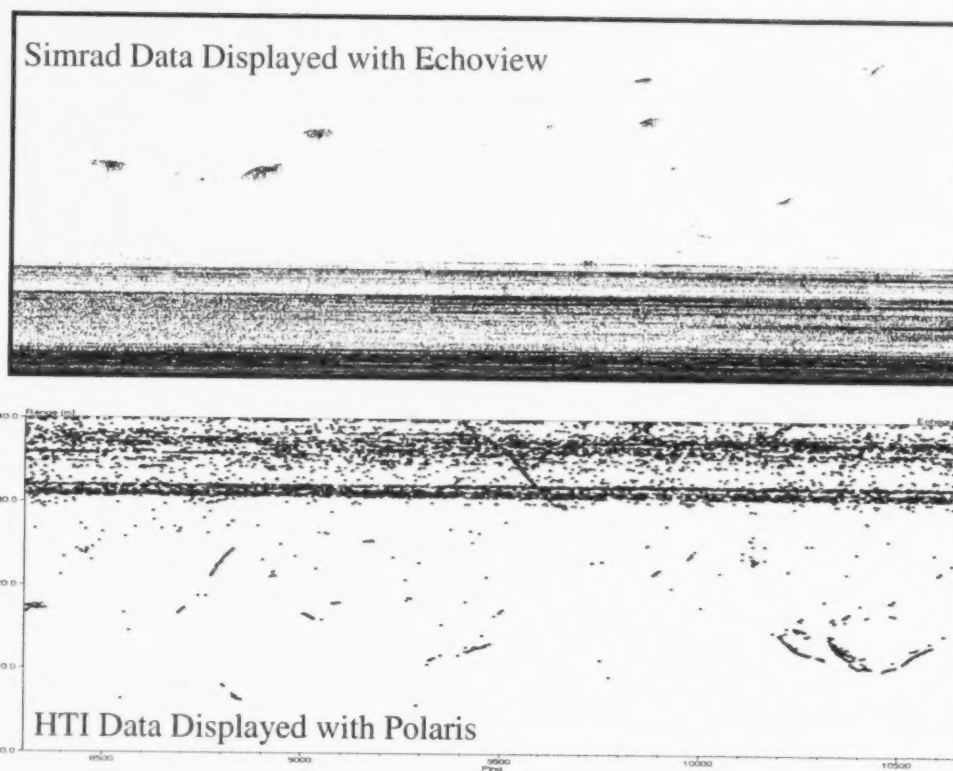


Figure 8. Echogram views used for data analyses for Simrad and HTI systems. Fish tracks are visible in both views. The two echograms display data from different days and the Y-axes (distance from the transducer in metres) are reversed due to the convention of each software program.

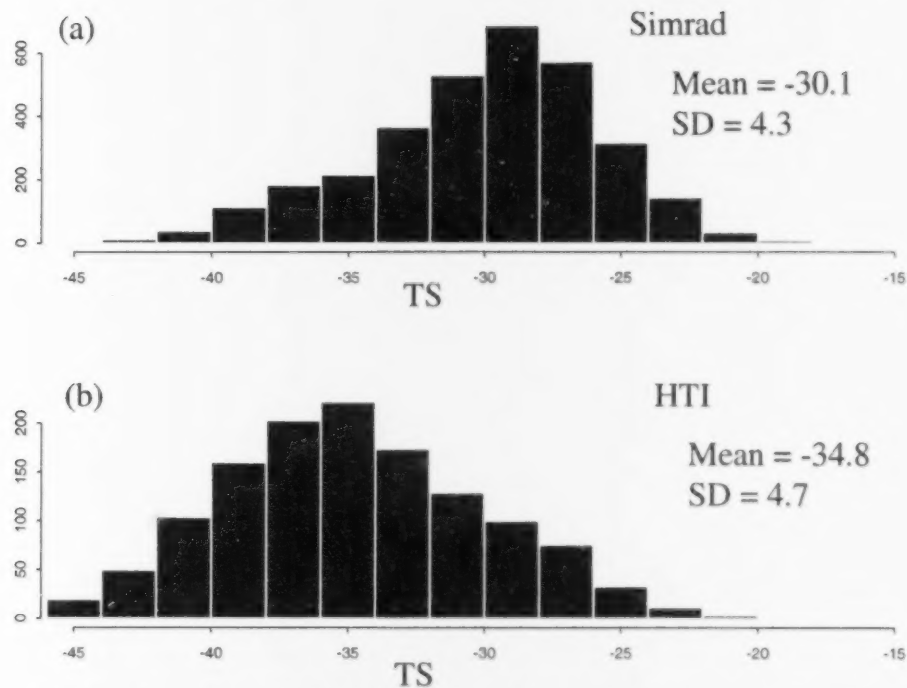


Figure 9. Target strength distributions for all fish tracks travelling both upstream and downstream for (a) the Simrad system and (b) the HTI system. Means and standard deviations for each are also presented. Note that the data was collected with the two systems at different times.

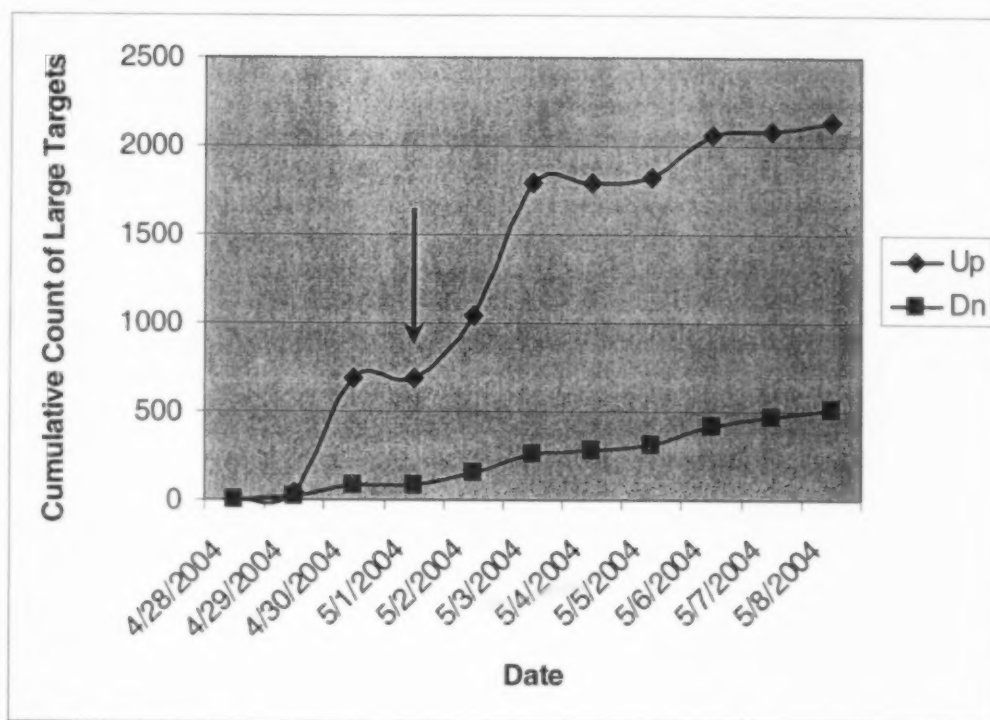


Figure 10. Cumulative count of large targets ( $\geq -33\text{dB}$ ) travelling upstream and downstream for Simrad and HTI systems. Data collection ended on 5/3/2004 with the Simrad system and continued on 5/4/2004 with the HTI system. The black vertical arrow points to the day of missing overnight data.

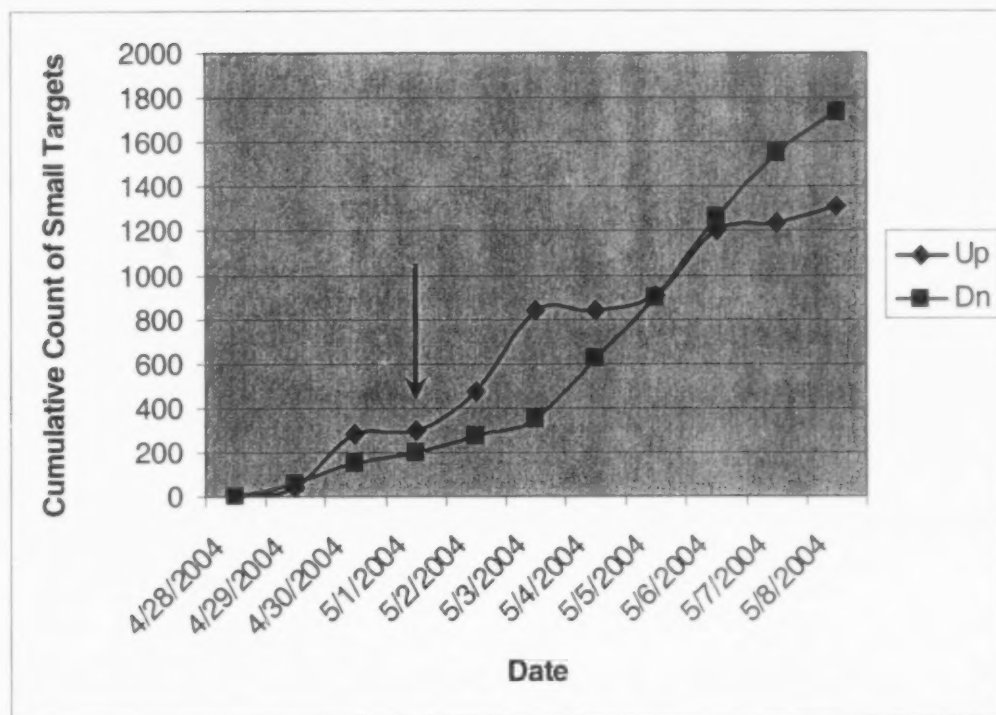


Figure 11. Cumulative count of small targets (< -33 dB) travelling upstream and downstream for Simrad and HTI systems. The black vertical arrow points to the day of missing overnight data.

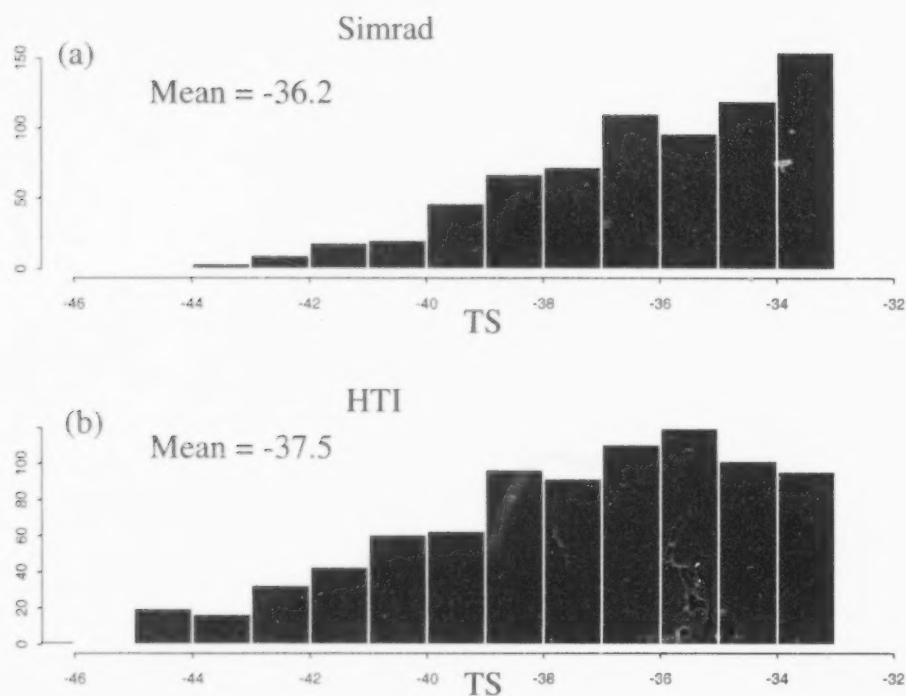


Figure 12. Target strength distributions of fish tracks less than -33dB which are believed to be species other than rainbow trout travelling both upstream and downstream, measured with (a) the Simrad system and (b) the HTI system. Mean TS values are presented.

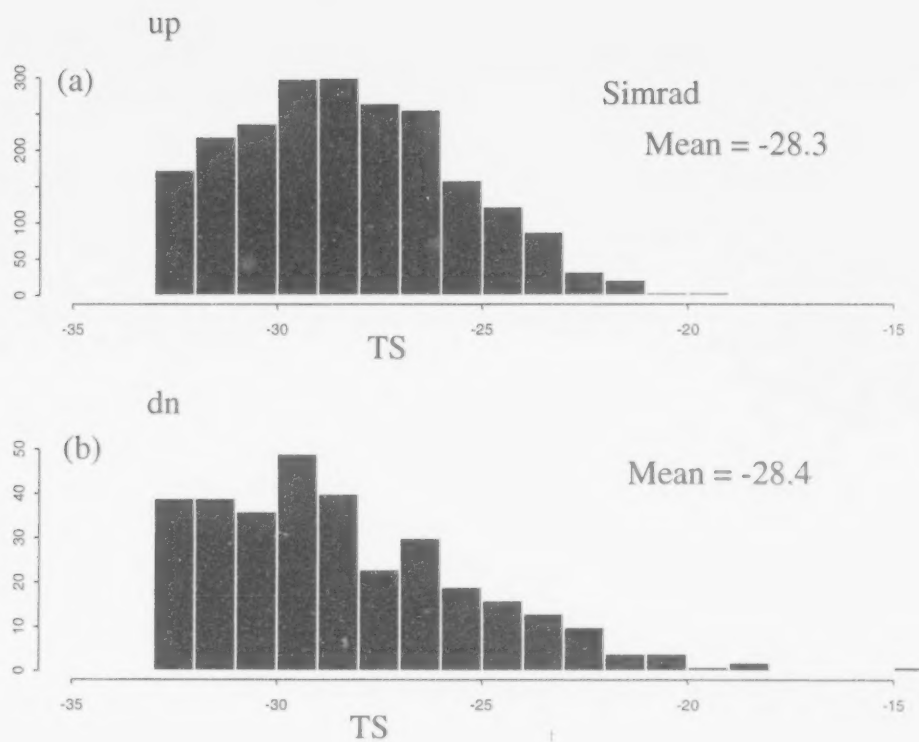


Figure 13. Target strength distributions of fish tracks greater than or equal to -33dB which are believed to be rainbow trout travelling (a) upstream and (b) downstream, measured with the Simrad system. Mean TS values are presented.

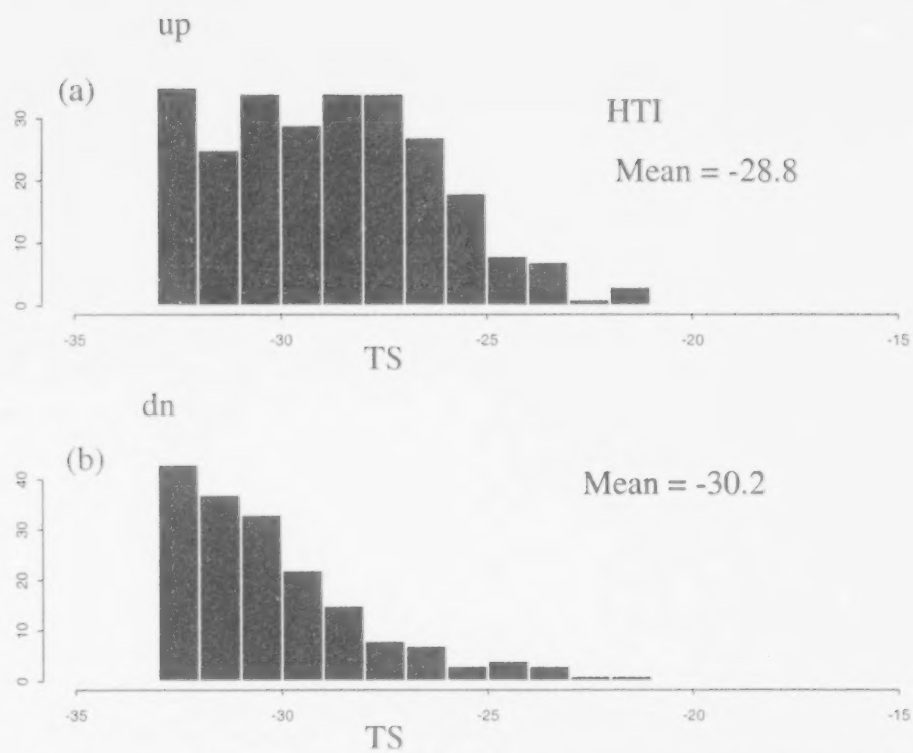


Figure 14. Target strength distributions of fish tracks greater than or equal to -33dB which are believed to be rainbow trout travelling (a) upstream and (b) downstream, measured with the HTI system. Mean TS values are presented.

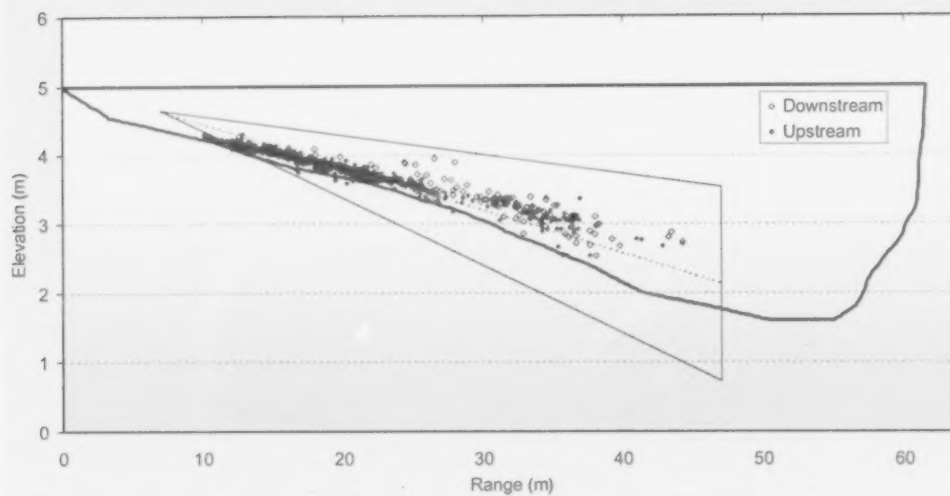


Figure 15. Side-view plot of the Michipicoten River showing the distribution of all upstream and downstream travelling fish measured with the Simrad system. Each dot represents the mean position of a fish in the water column as it traveled through the beam.

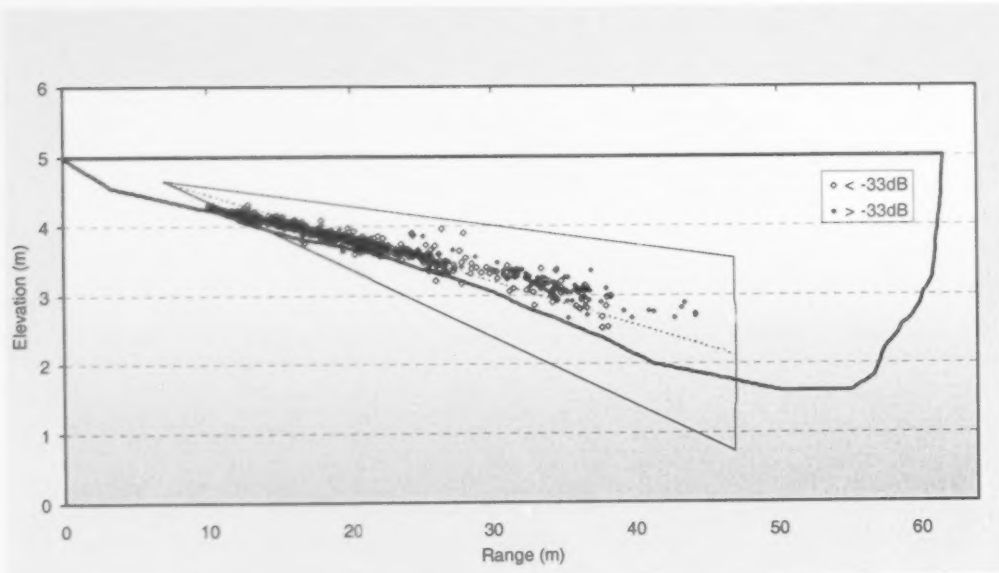


Figure 16. Side-view plot of the Michipicoten River showing the distribution of large ( $\geq -33$  dB) and small ( $< -33$  dB) fish measured with the Simrad system. Each dot represents the mean position of a fish in the water column as it traveled through the beam.

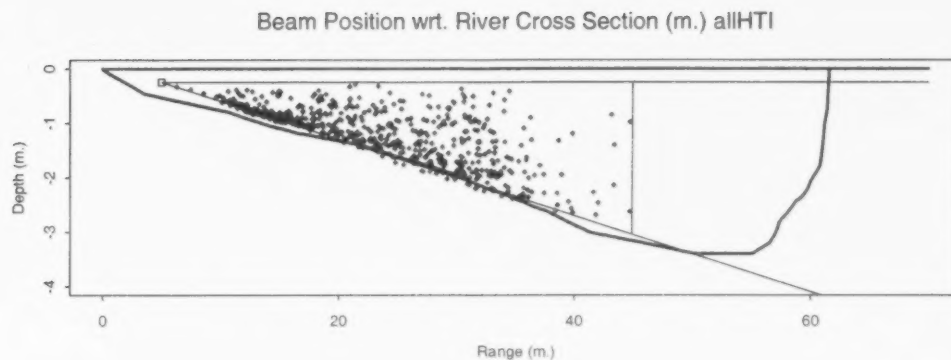


Figure 17. Side-view plot of the Michipicoten River showing the distribution of all fish measured with the HTI system. Each dot represents the mean position of a fish in the water column as it traveled through the beam.

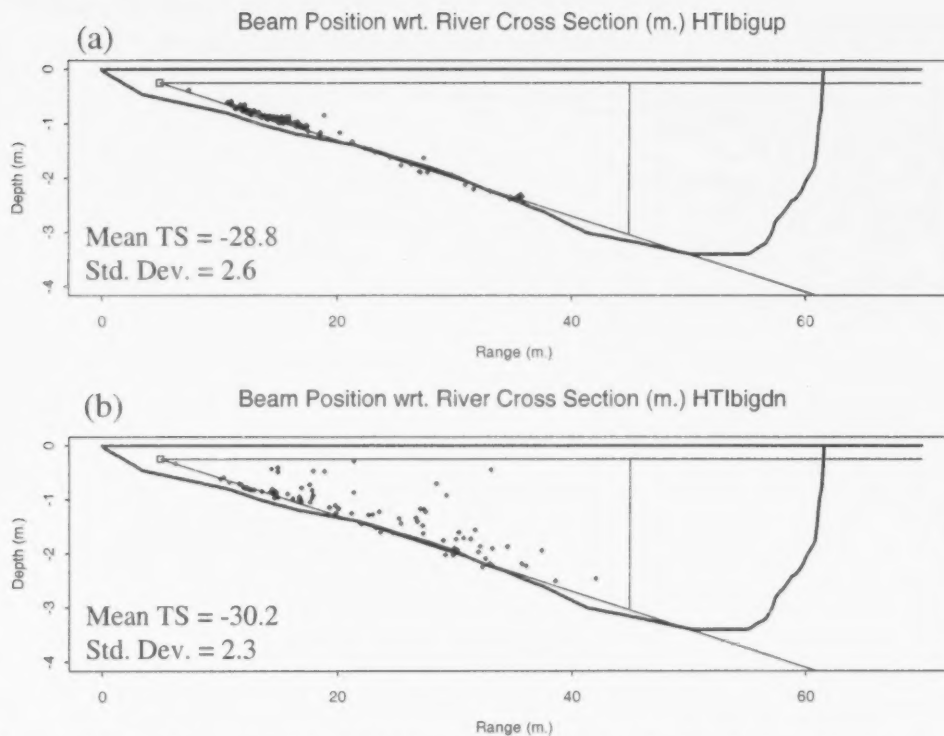


Figure 18. Side-view plots of the Michipicoten River showing the distribution of (a) large upstream and (b) large downstream travelling fish measured with the HTI system. Each dot represents the mean position of a fish in the water column as it traveled through the beam. Mean target strengths and standard deviations are also presented.

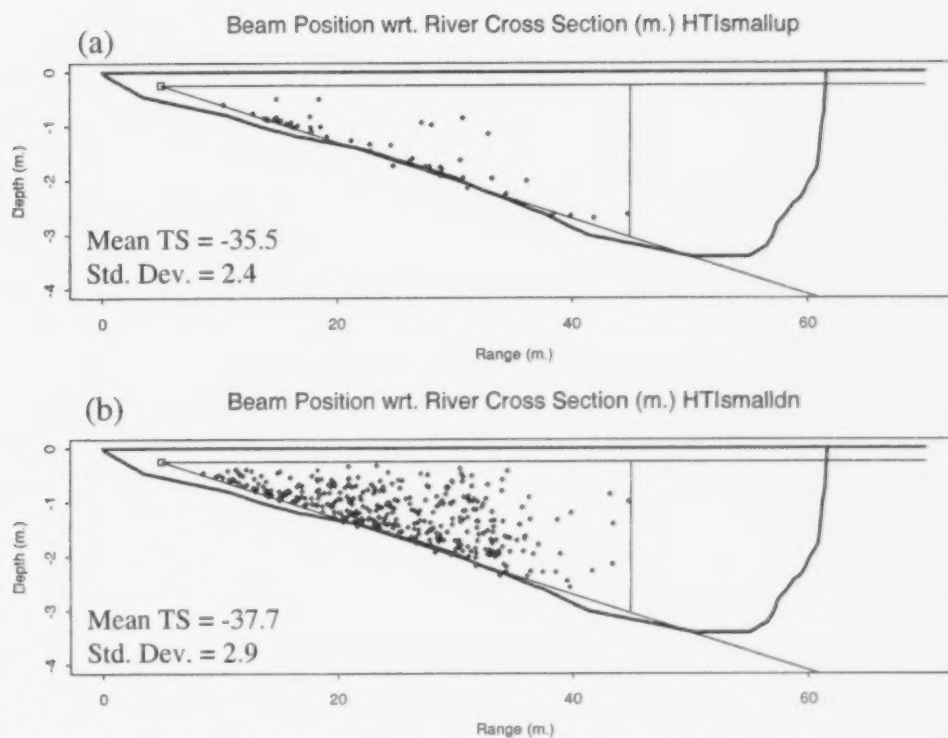


Figure 19. Side-view plots of the Michipicoten River showing the distribution of (a) small upstream and (b) small downstream travelling fish measured with the HTI system. Each dot represents the mean position of a fish in the water column as it traveled through the beam. Mean target strengths and standard deviations are also presented.

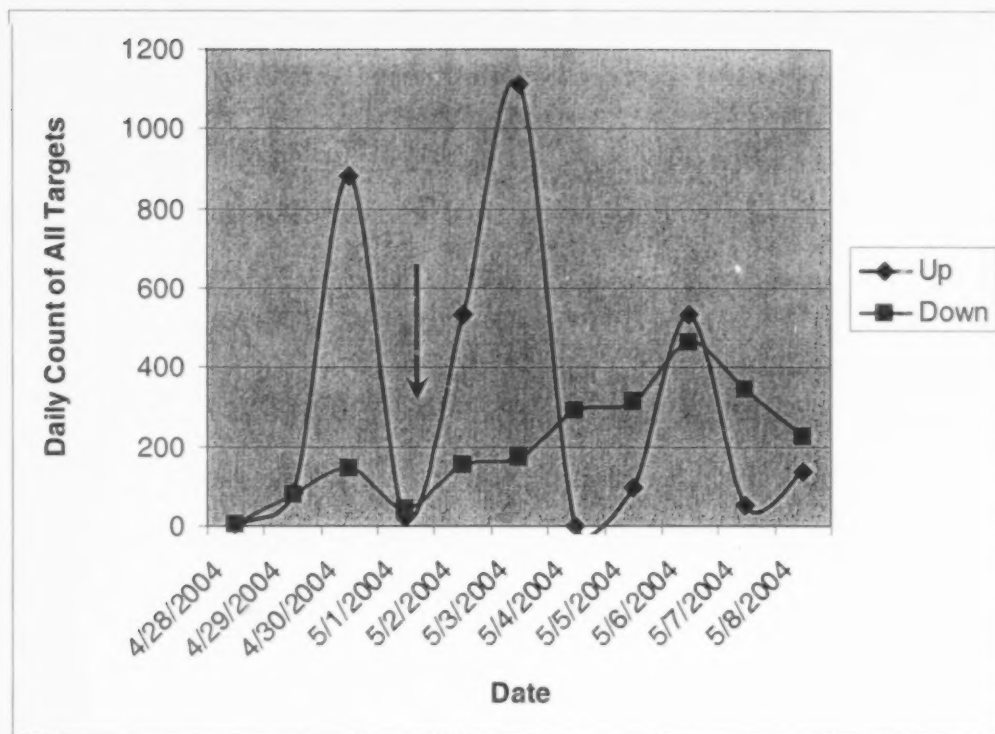


Figure 20. Overall run timing curves for the Simrad and HTI data combined for upstream and downstream travelling fish of all sizes. The vertical black arrow marks the day of missing overnight data.

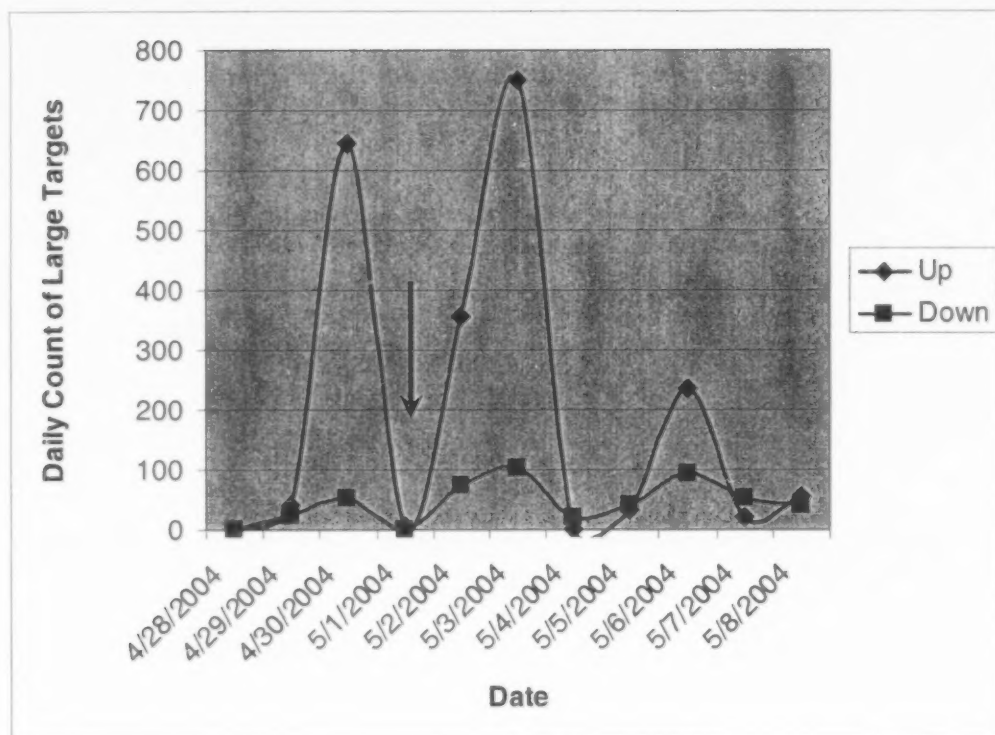


Figure 21. Overall run timing curves for the Simrad and HTI data combined for large upstream and downstream travelling fish. The vertical black arrow marks the day of missing overnight data.

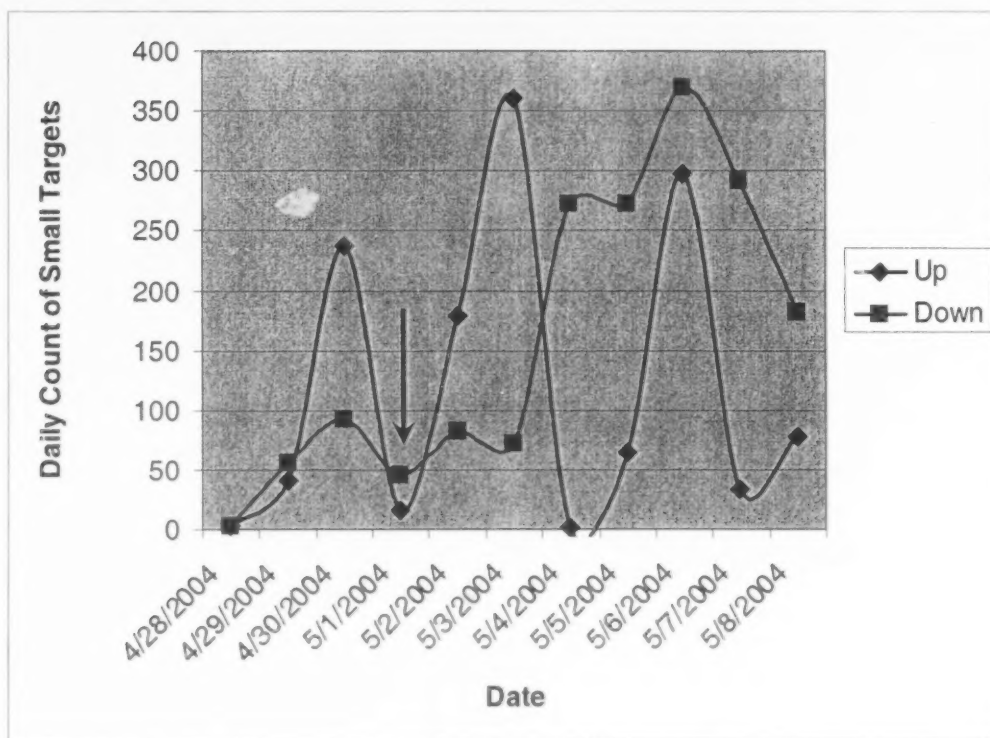


Figure 22. Overall run timing curves for the Simrad and HTI data combined for small upstream and downstream travelling fish. The vertical black arrow marks the day of missing overnight data.

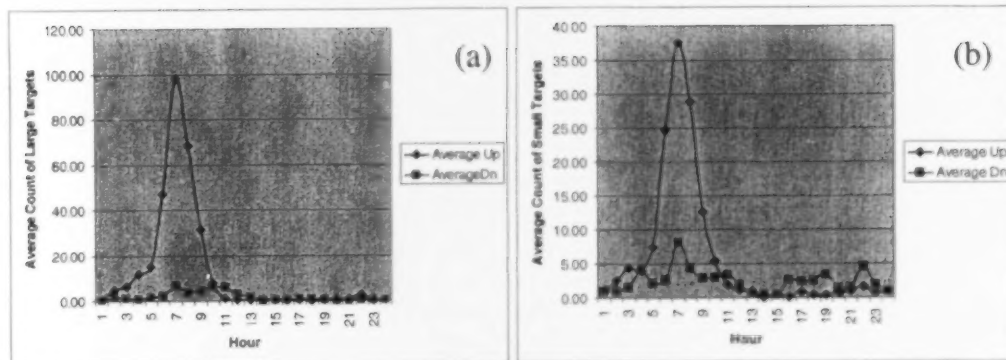


Figure 23. Average hourly count of (a) large fish and (b) small fish travelling upstream and downstream vs. time of day.

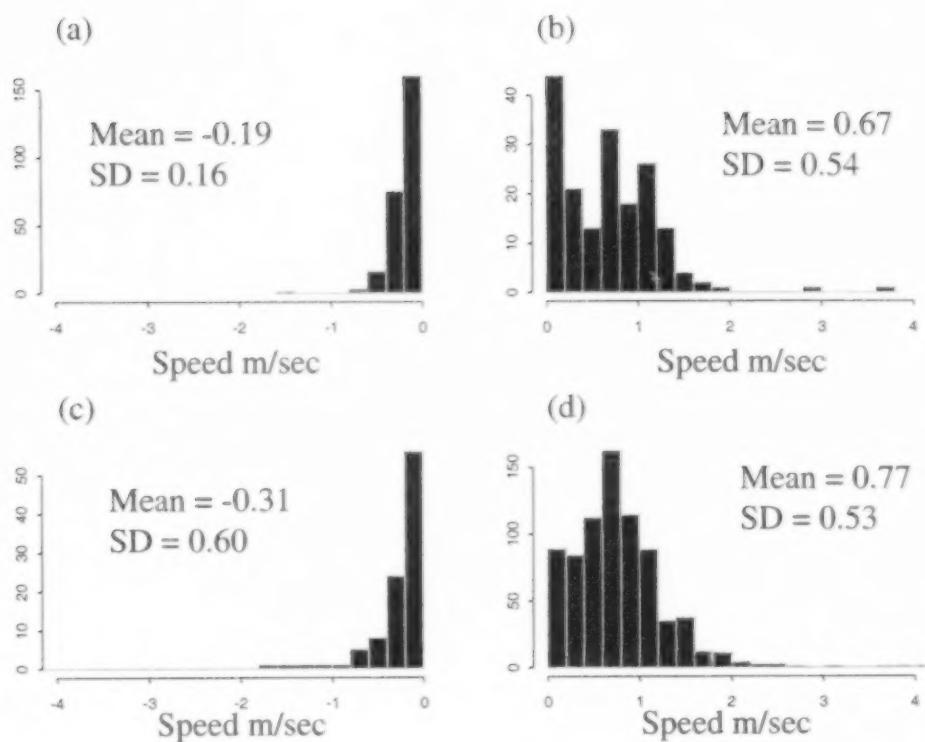


Figure 24. Fish X-speed distributions measured with the HTI system for (a) large upstream fish, (b) large downstream fish, (c) small upstream fish, and (d) small downstream fish.

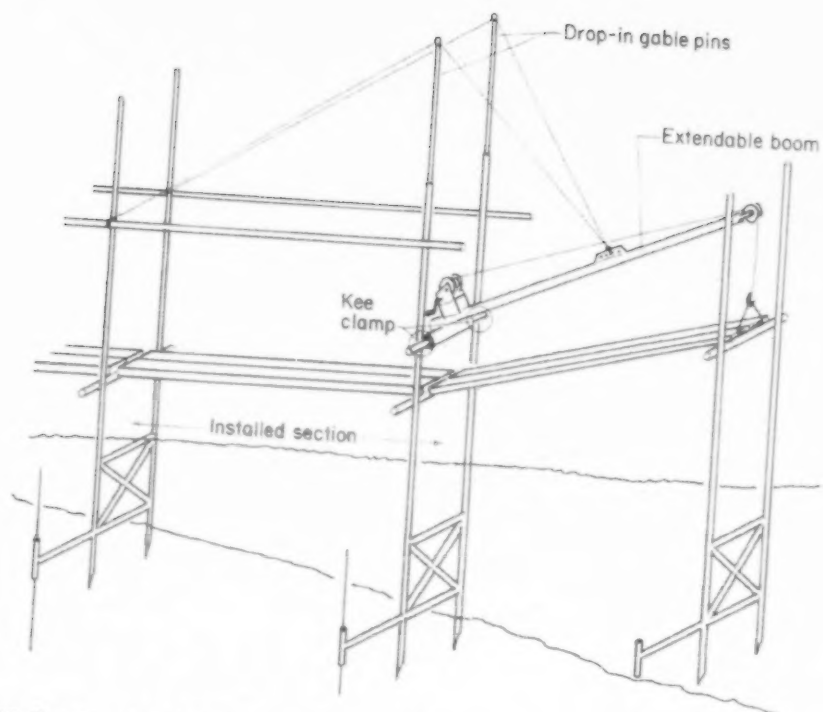


Figure 25. Sectional weir design suggested for the right-bank to divert near shore fish passage out through the far field of the acoustic beam.

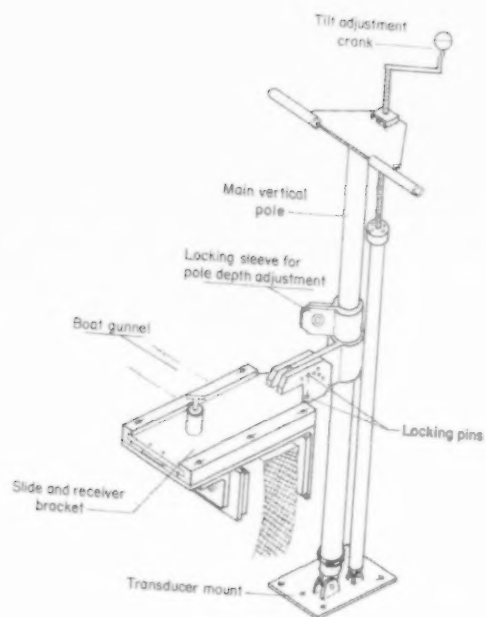


Figure 26. Any selected transducer can be attached to an adjustable pole mount designed for deploying the DIDSON imaging sonar system.

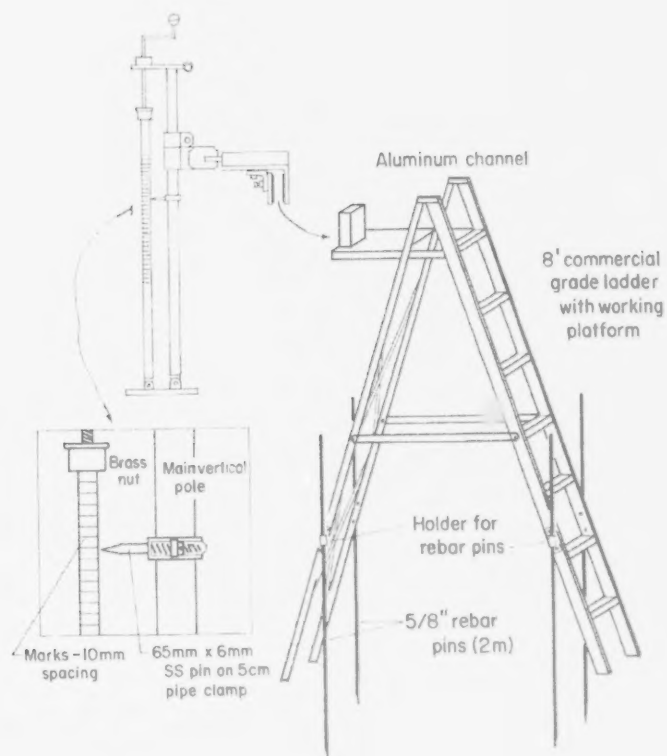


Figure 27. The adjustable pole mount can be attached to a modified stepladder anchored to the river bottom with four 5/8 inch steel pins. This arrangement is suitable for use on the Michipicoten River.

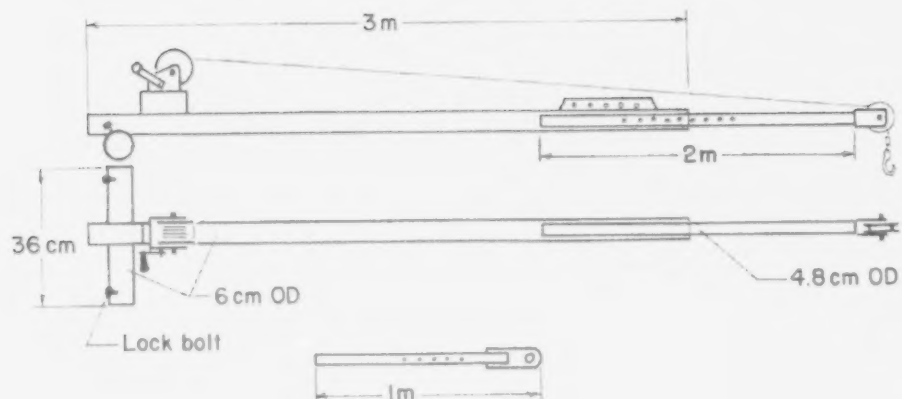


Figure 28. This long boom with a mounted trailer winch is designed to allow the installation of additional weir sections from the end of the last installed section.

